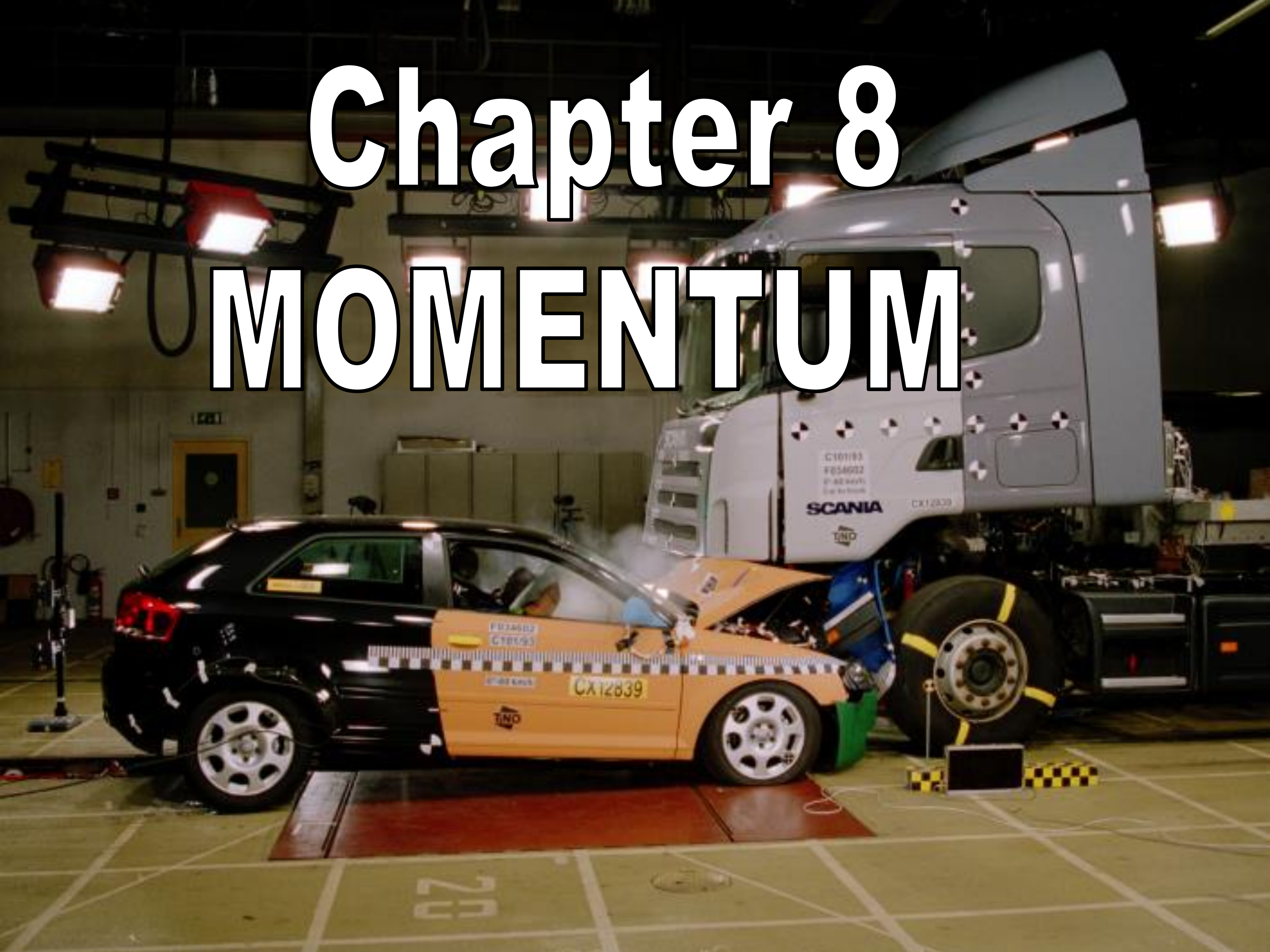
Chapter 8
MOMENTUM



Chapter 7: Momentum

I. Momentum (7.1)

A. momentum– “inertia in motion”

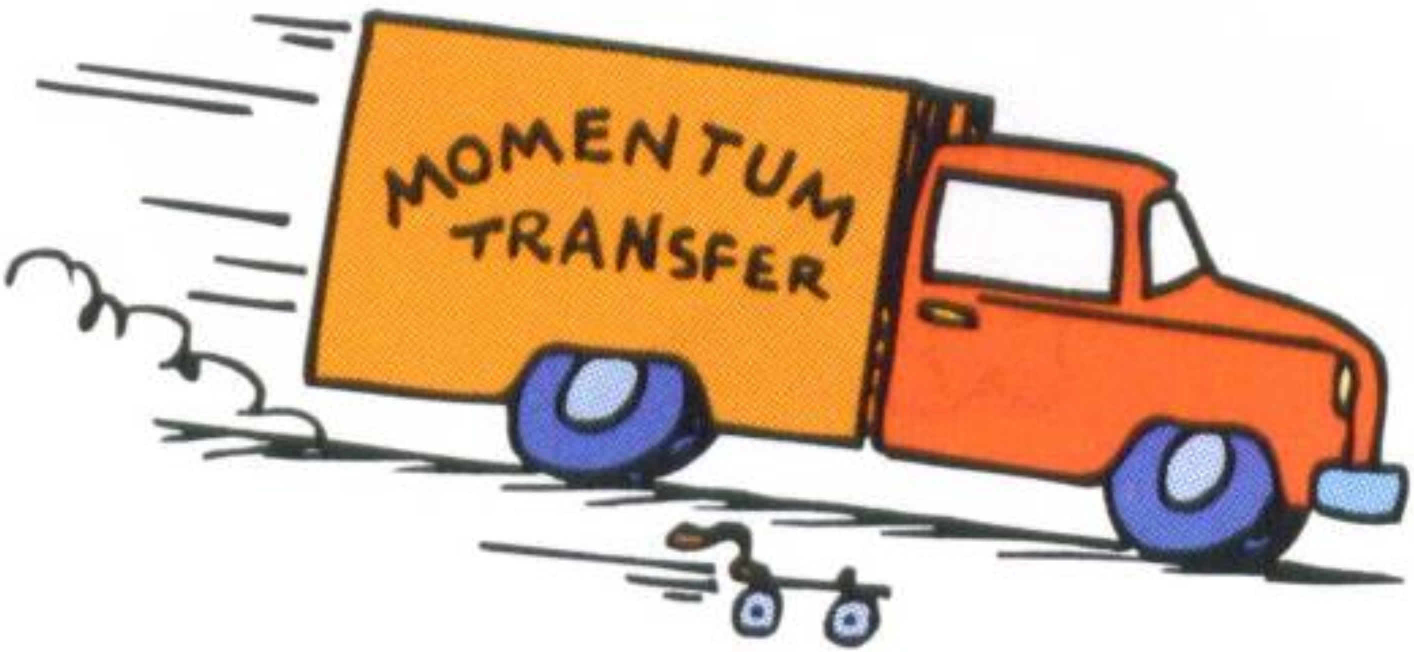
1. Mass of an object multiplied by its velocity

Momentum = mass x velocity

$$p = mv$$

2. A moving object can have large momentum with either **large mass** or **high speed**

$$p = mv$$



B. An object at **rest** has **zero momentum** (velocity = 0)

II. Impulse Changes Momentum (7.2)

A. The **greater the force** on an object the **greater the change in acceleration**

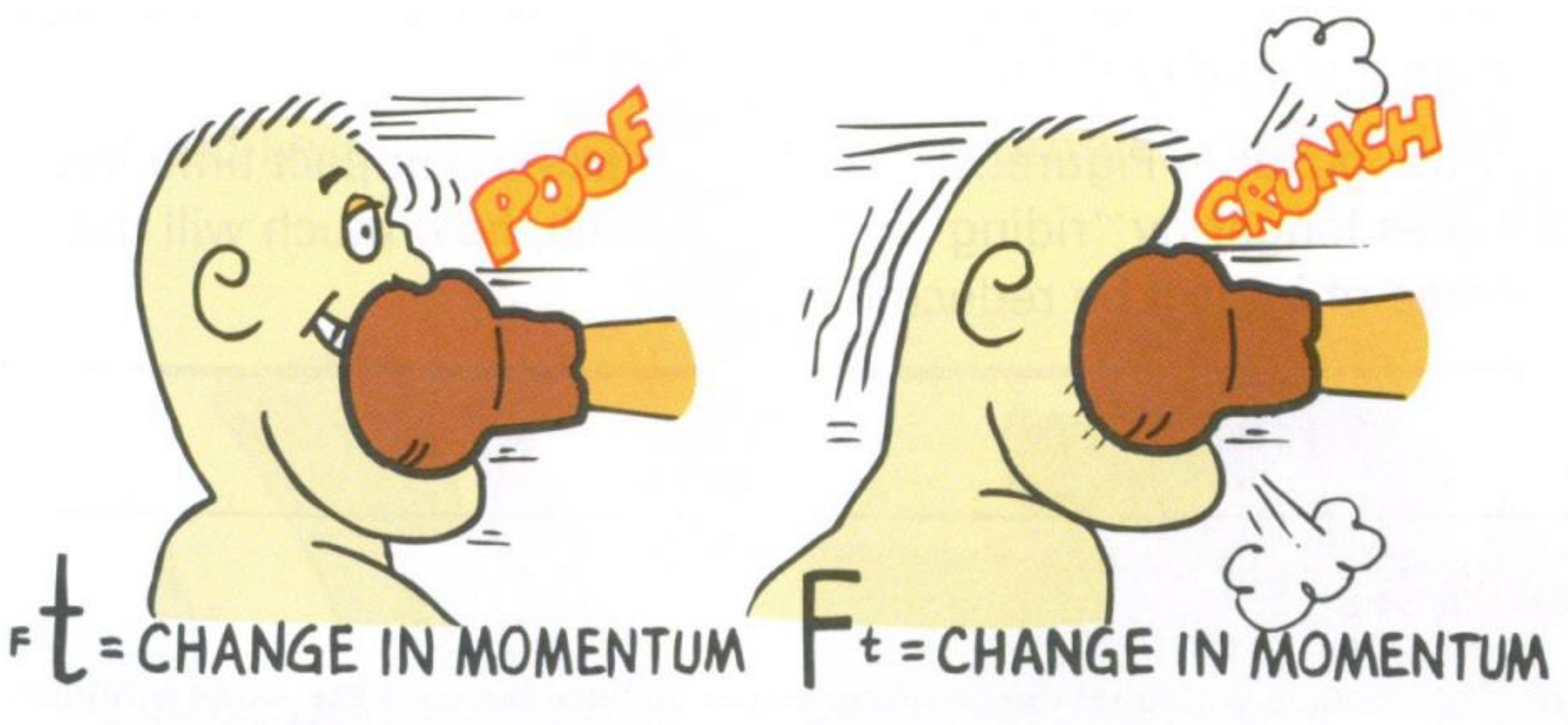
1. Apply force over **longer time** and produce greater change in momentum

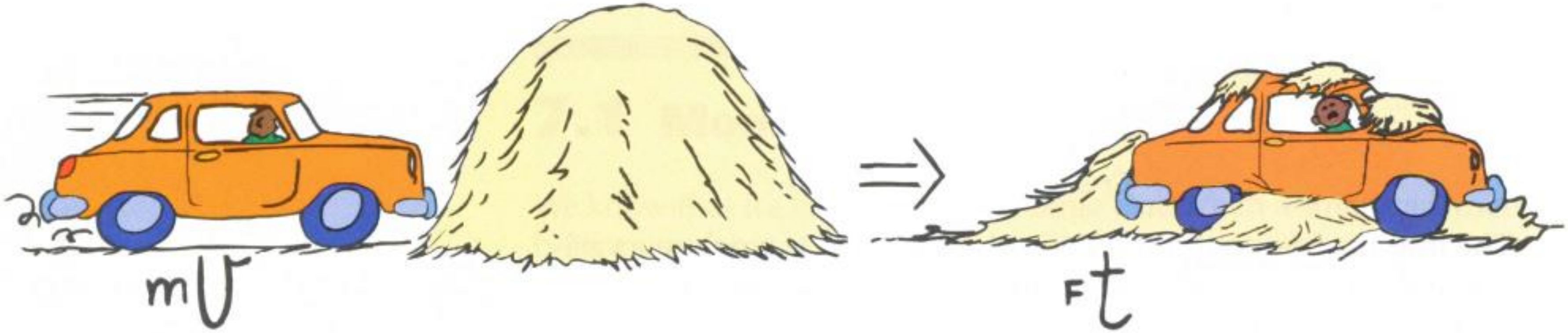
a. **Force x time** = **impulse**

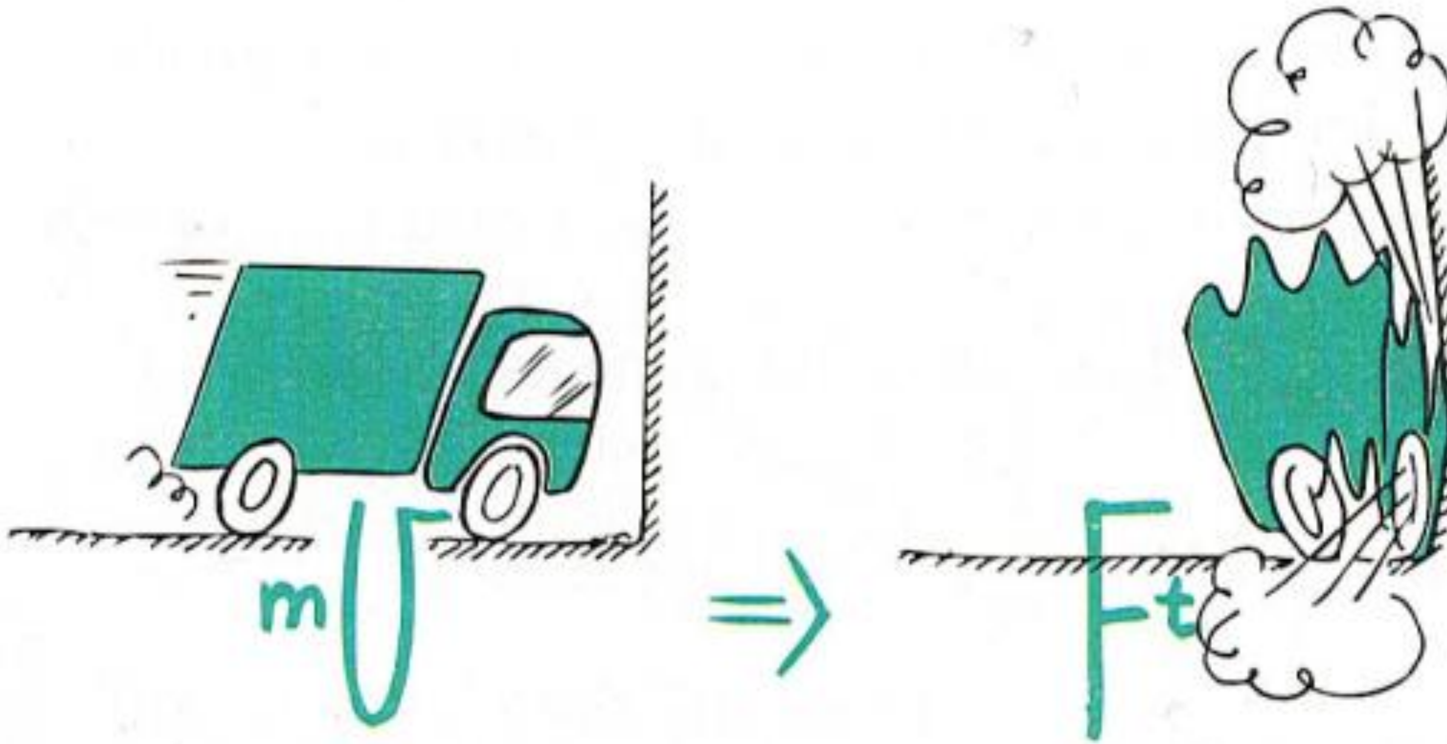
b. ***Impulse = change in momentum***

2. The greater the **impulse** on something, the greater the change in **momentum**

$$Ft = \Delta(mv)$$




mv
Ft


mv
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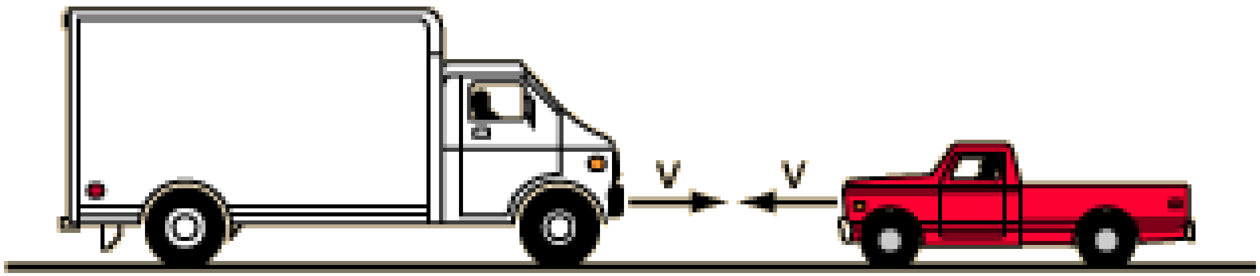


Force	F	$=$	F
Impulse	F_t	$=$	F_t
Change in momentum	$m\Delta v$	$=$	$m\Delta v$
Acceleration	ma	$=$	ma

Rearrange Newton's second law (*F* = *ma*)

$$F = ma = m\left(\frac{\Delta v}{\Delta t}\right)$$

$$F\Delta t = m\Delta v$$

if we let Δt be simply t, then:

$$Ft = \Delta mv$$

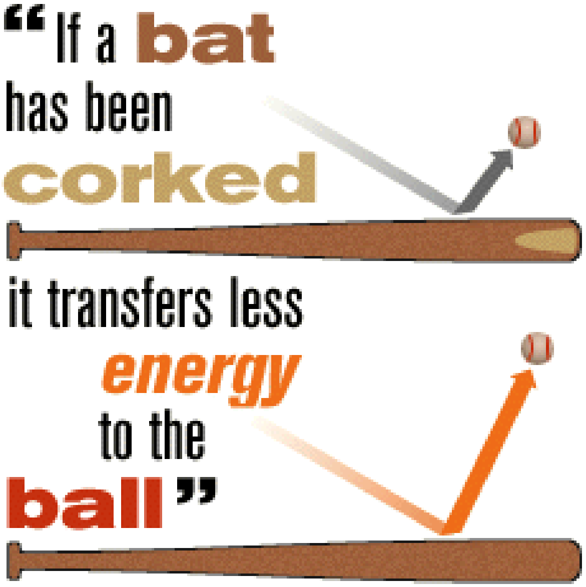
B. Increasing Momentum

1. To increase **momentum** of object apply **greatest** **force** for as **long as possible**

2. Impact forces– means average force of impact

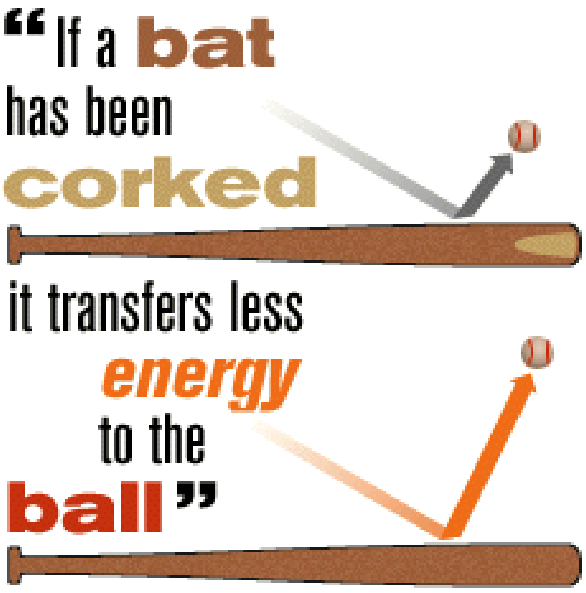
a. **Impact** refers to a force (measured in **N**)

b. **Impulse**-Impact force x time (measured in **N-s**)



C. Decreasing Momentum

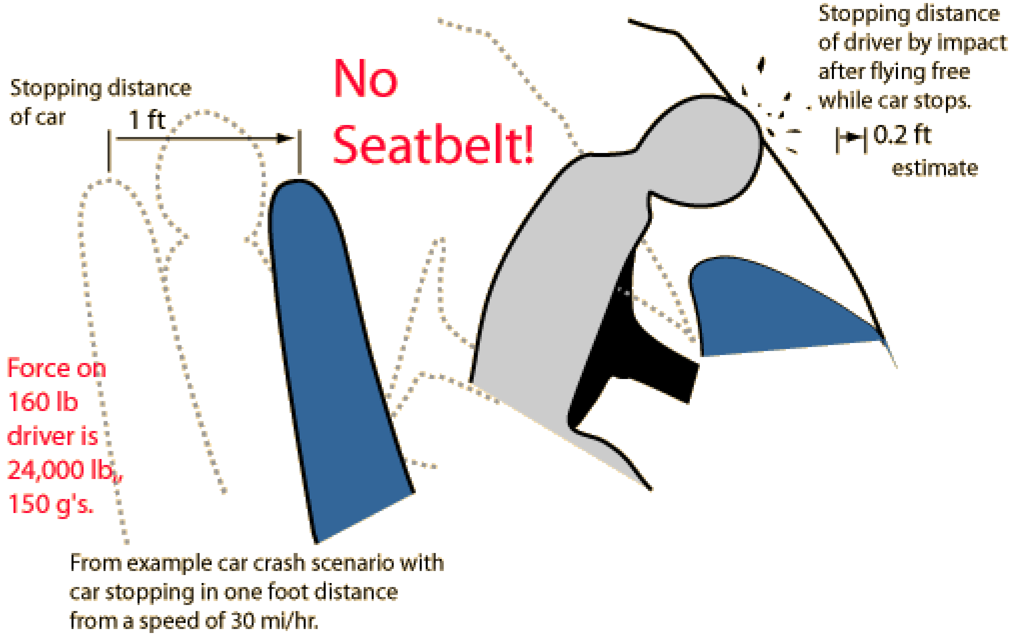
1. Longer impact time **reduces force** of impact and decreases the resulting **deceleration**

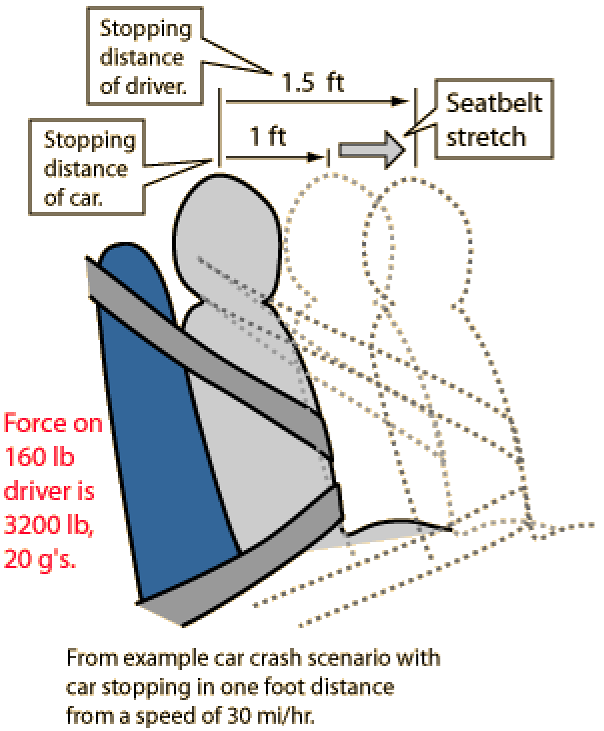


2. Extend **impact time** to <u>reduce</u> **impact force**

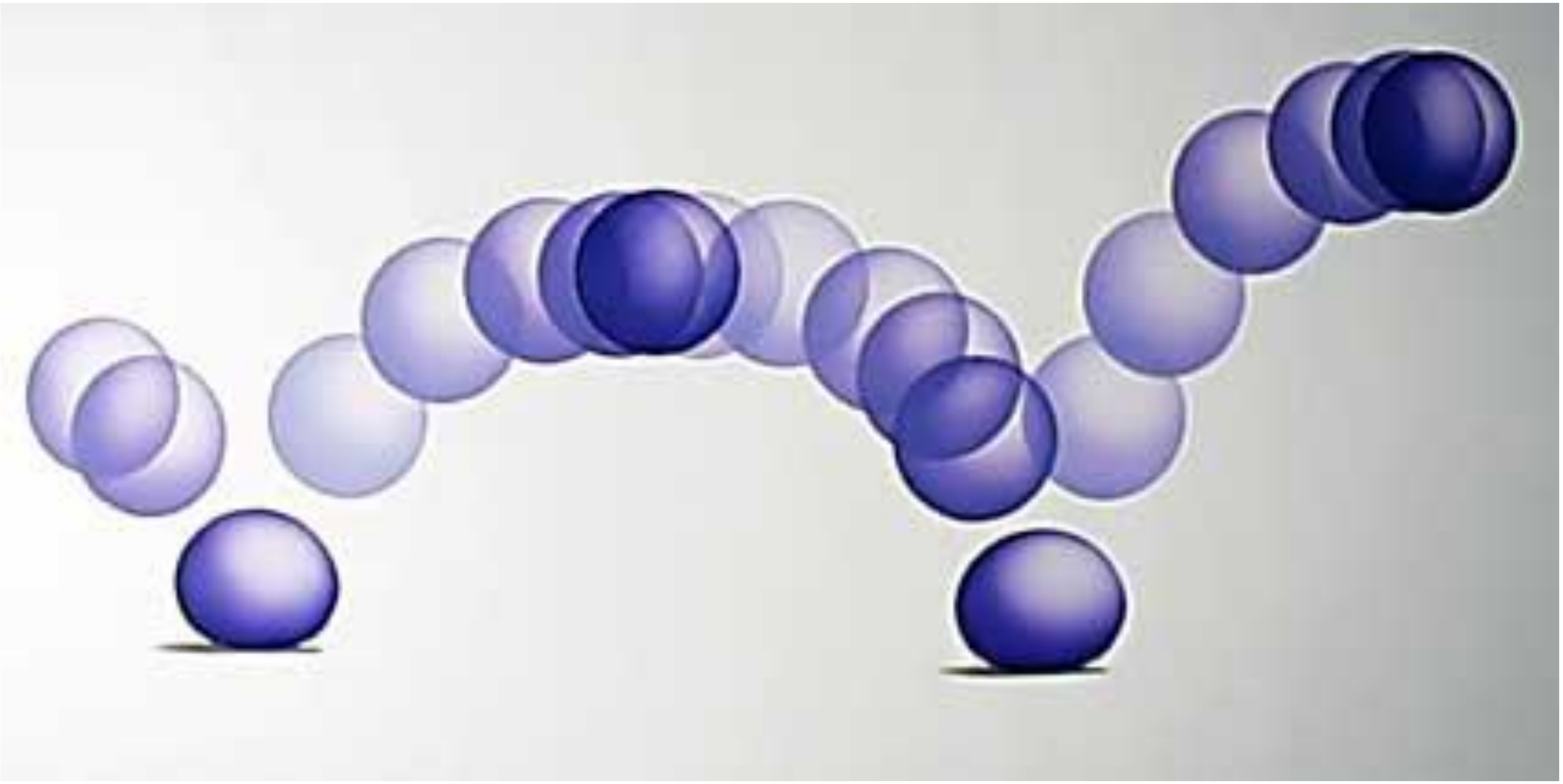
a. evident in design of cars

b. evident when looking at floors (concrete, wood, etc.)





III. Bouncing (7.3)-impulses are greater when bouncing takes place



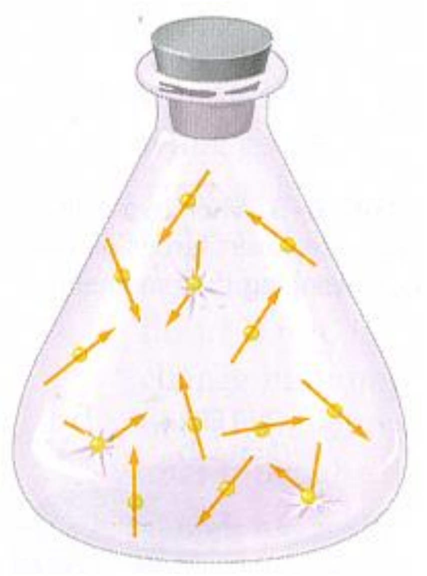
IV. Conservation of Momentum (7.4)

A. To **accelerate** an object you **must apply a force** to it

B. To **change momentum** of an object, you must **exert an impulse** to it.

C. In either case, the **force** or **impulse** must be exerted by something **outside** the object.

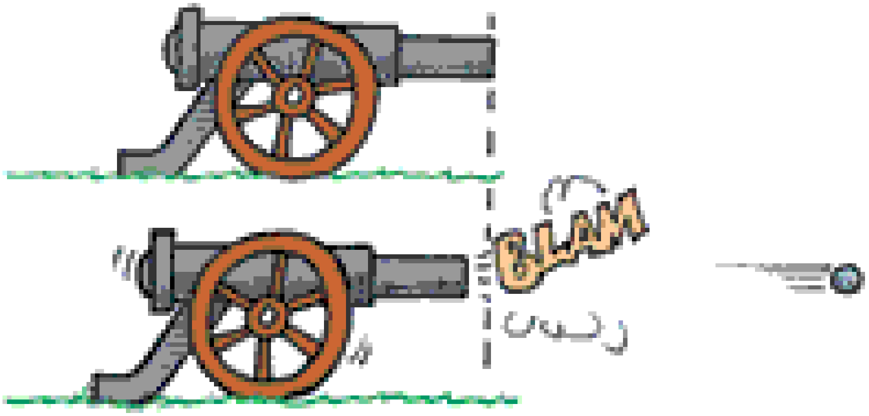
1. Internal forces won't work
2. **Internal forces** come in **balanced pairs** and cancel within the object
3. If no external force is present - no change in momentum is possible.

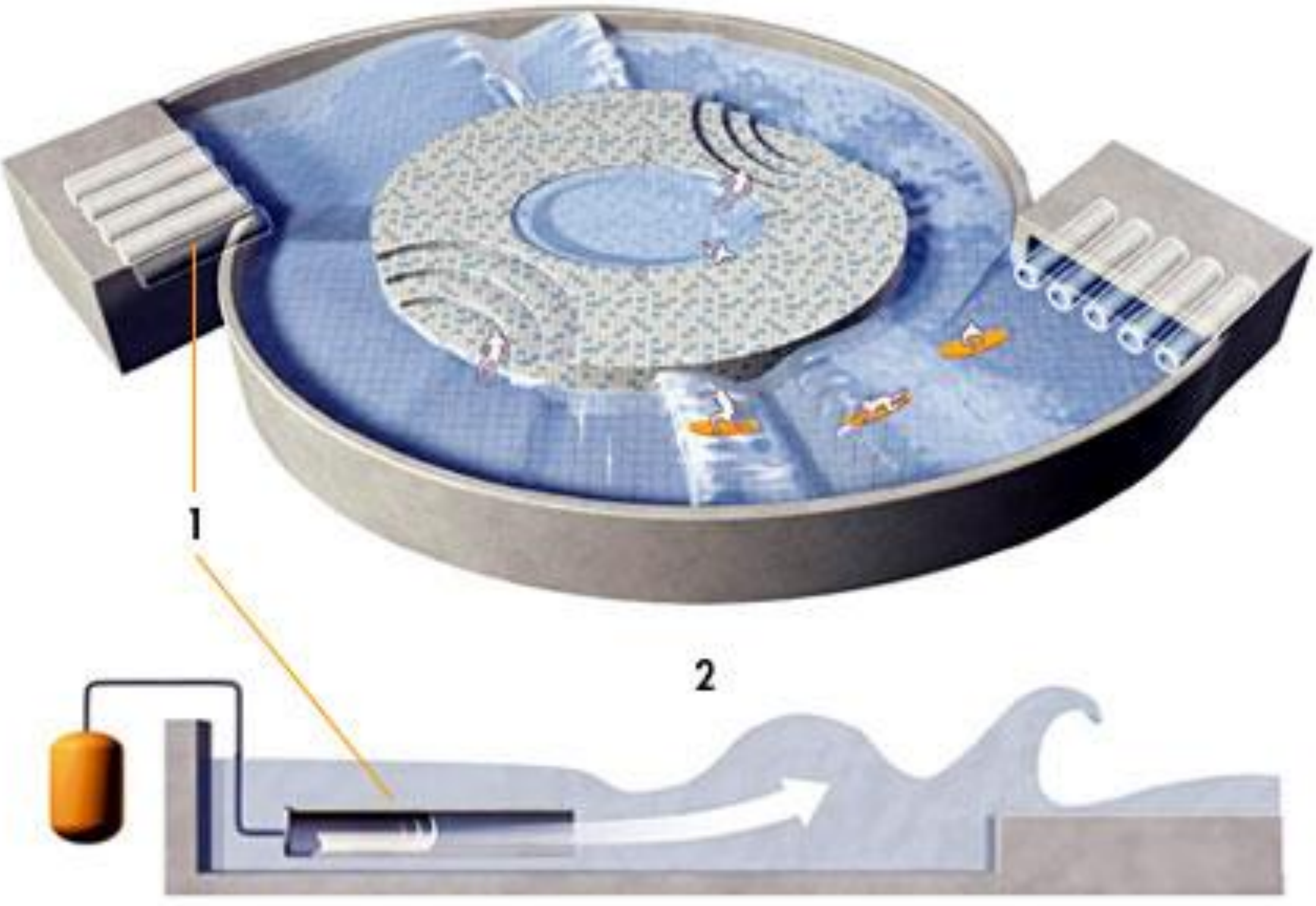


D. Cannon example

1. Cannon at rest—
momentum = 0 (velocity is 0)

2. After firing - net momentum (or total momentum) is **still 0.**

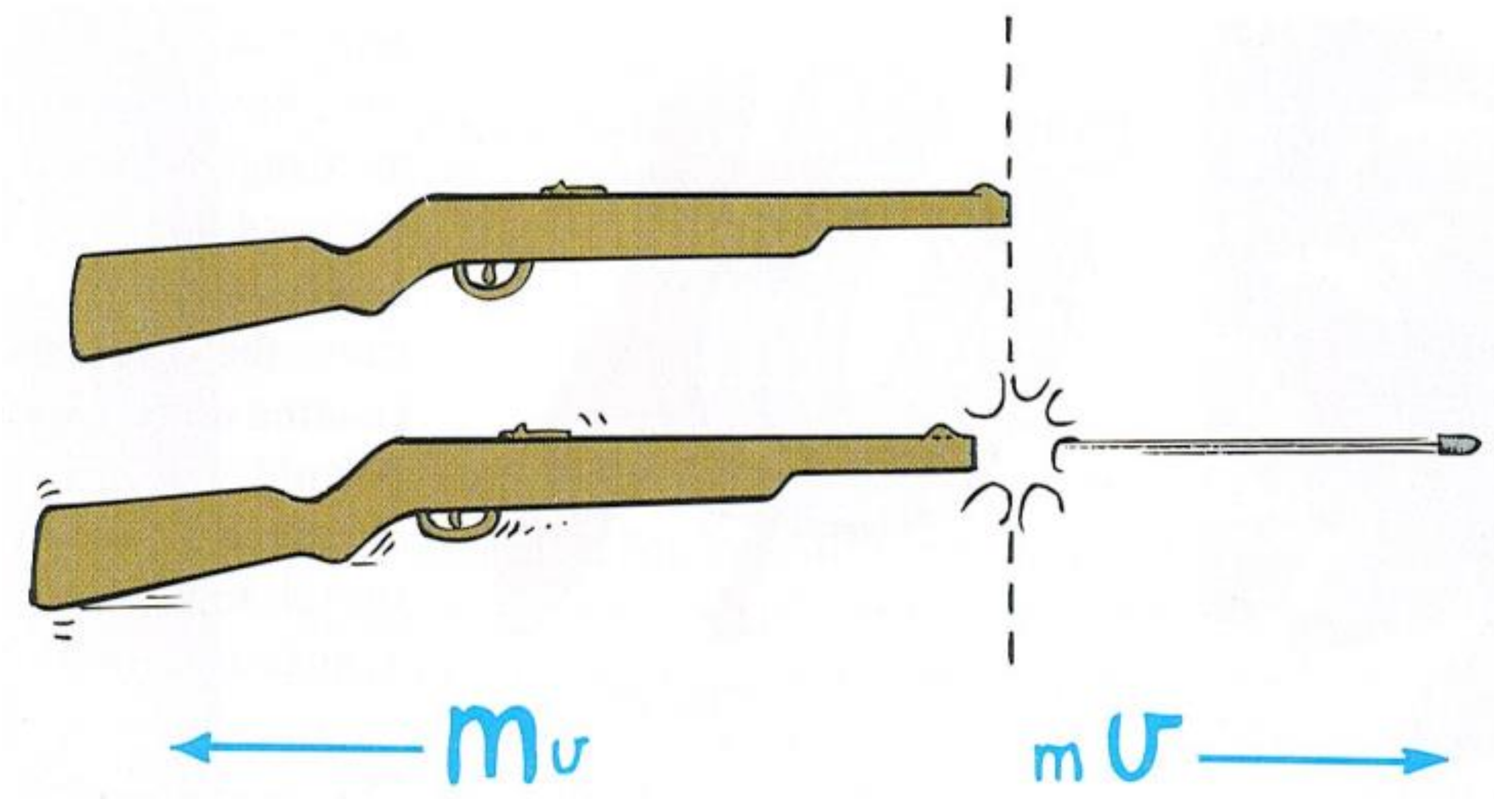



1
2

E. Momentum is a vector quantity

1. has <u>both </u>**magnitude** and **direction**

2. Therefore they can be **cancelled**

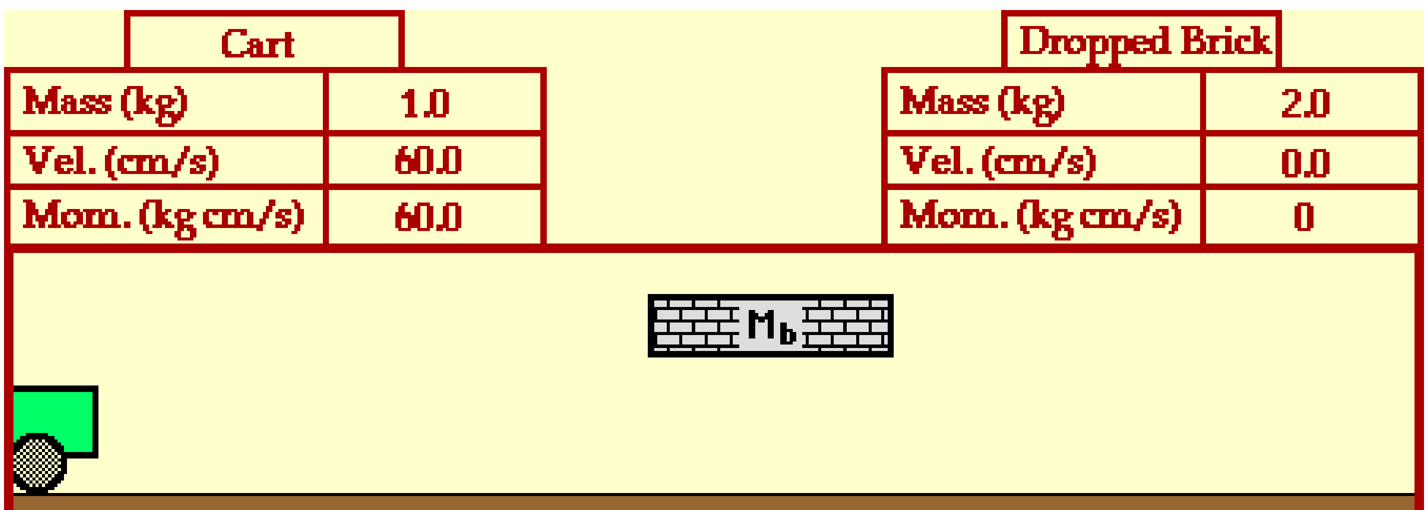


3. Magnitude of cannon ball and cannon are **equal and opposite in direction** (they cancel each other)

4. **If no net force or net impulse acts on a system the momentum of that system cannot change**

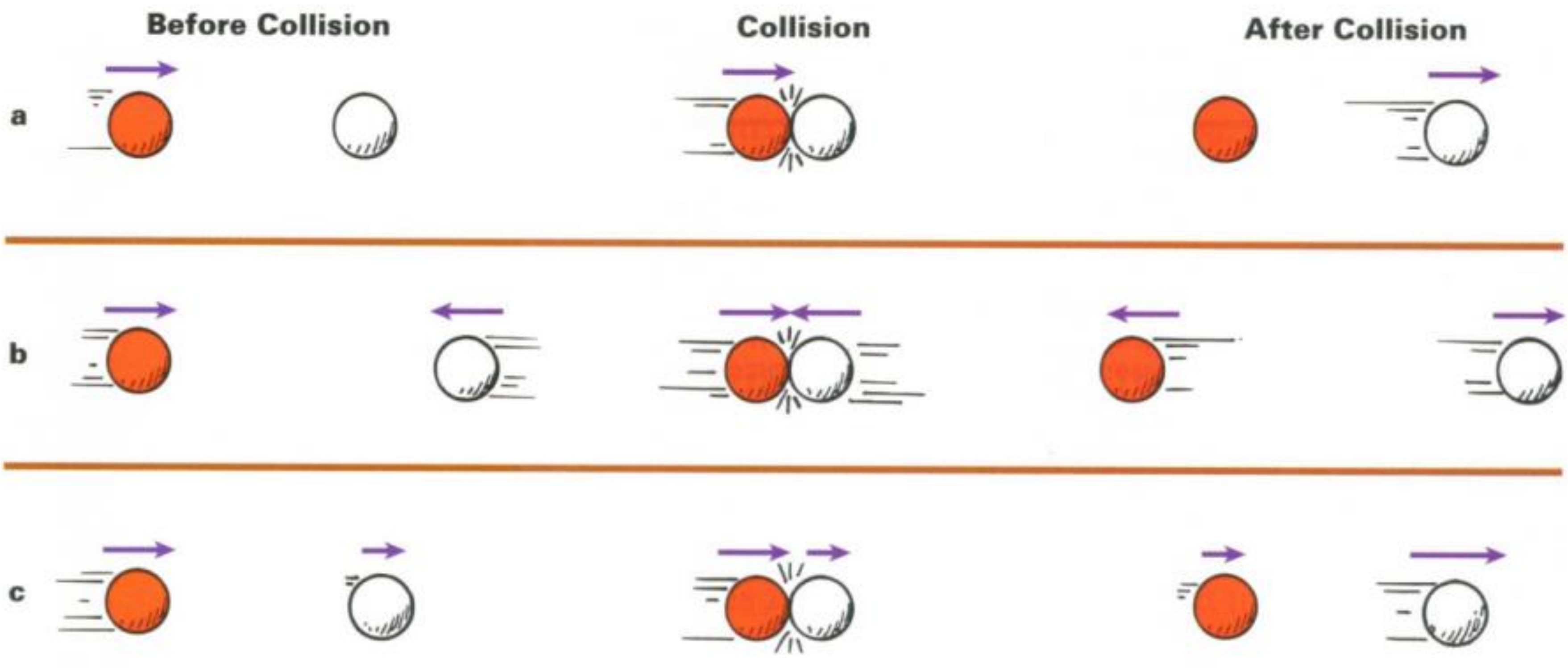
5**. Law of conservation of momentum**–

In the absence of an external force, the momentum of a system remains unchanged



V. Collisions (7.5)

A. **Elastic Collisions**– *when objects collide without being permanently deformed and without generating heat*



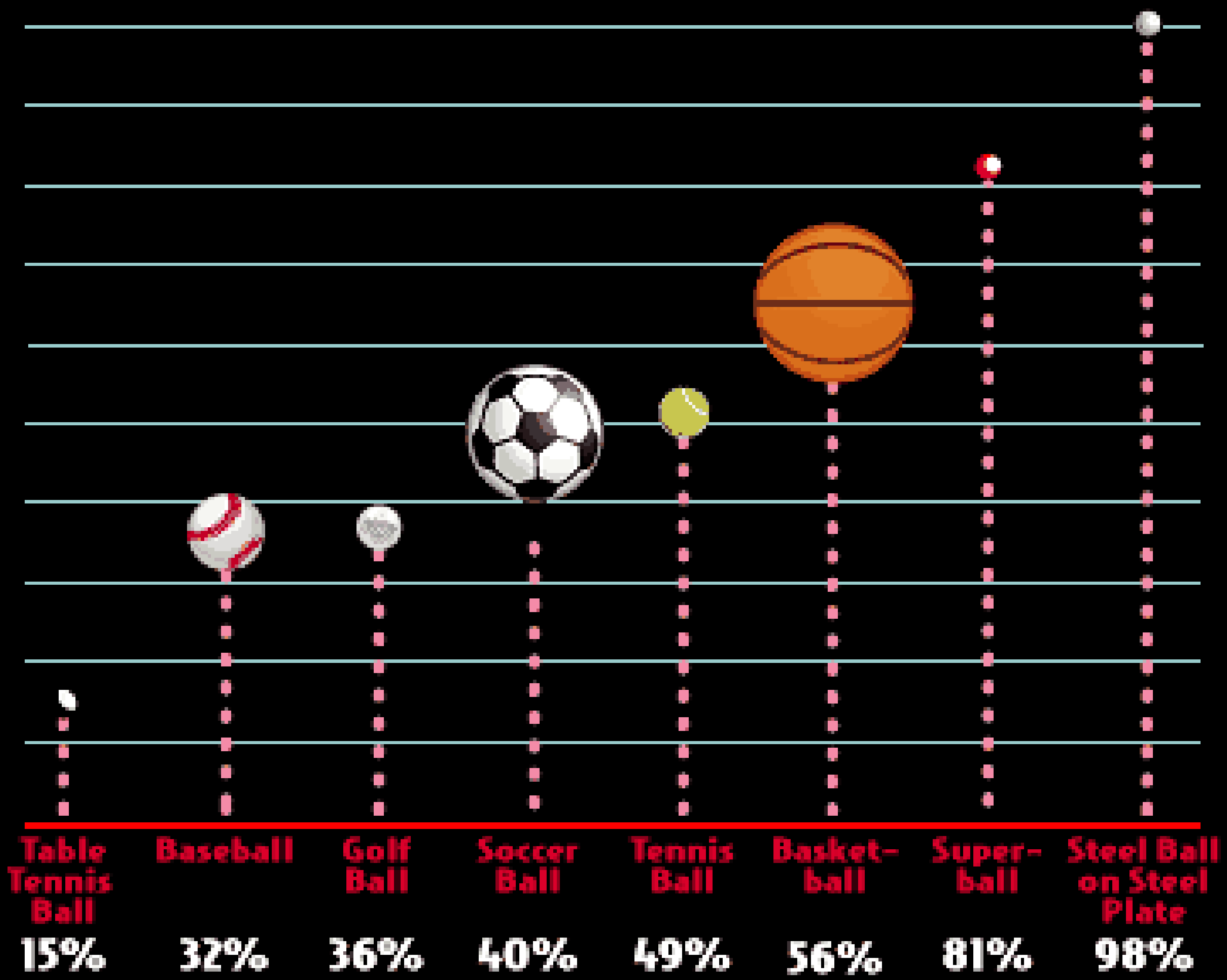
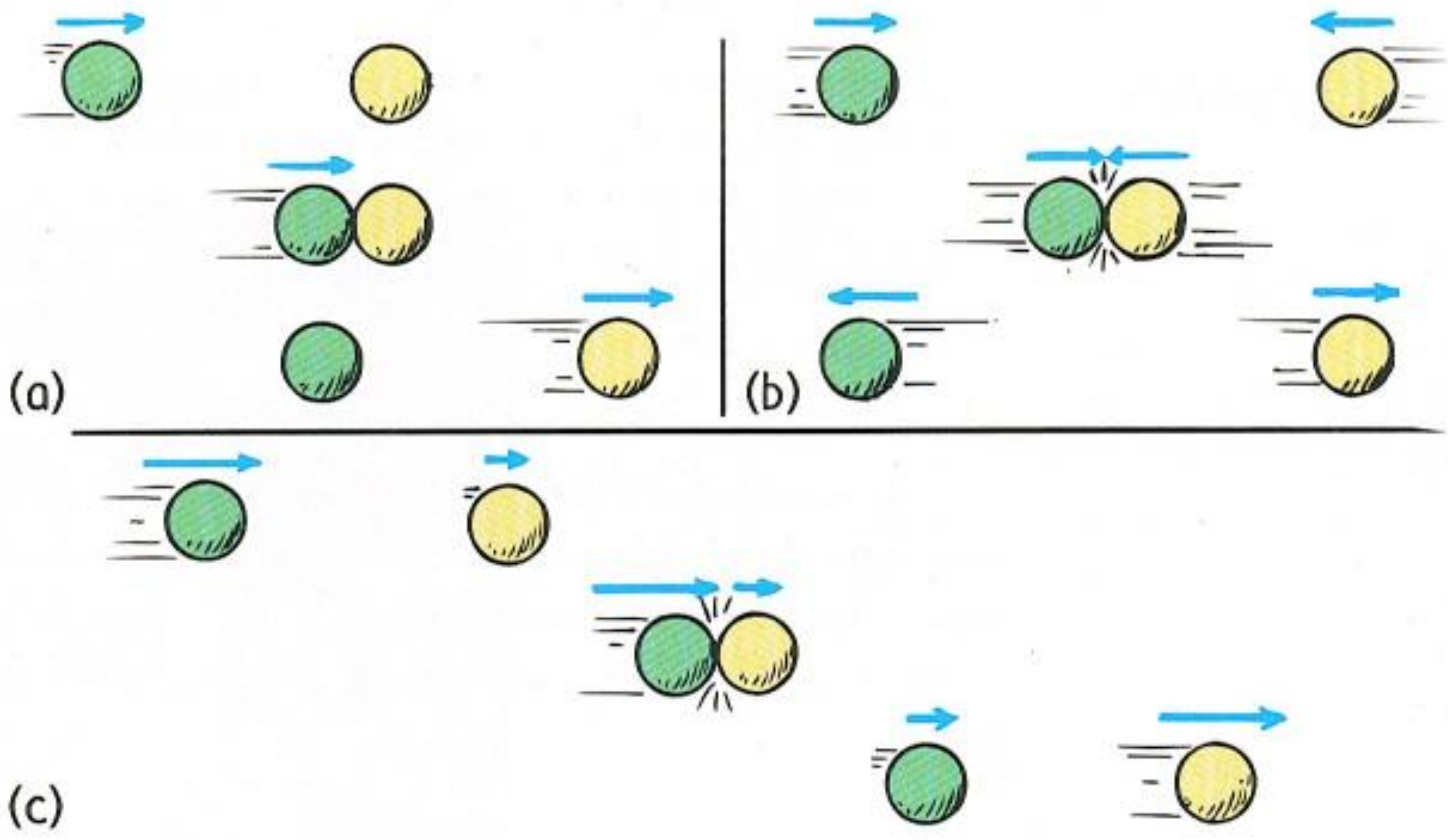


Table Tennis Ball
15%
Baseball
32%
Golf Ball
36%
Soccer Ball
40%
Tennis Ball
49%
Basket-ball
56%
Super-ball
81%
Steel Ball on Steel Plate
98%

1. Momentum is **transferred** from first object to second.

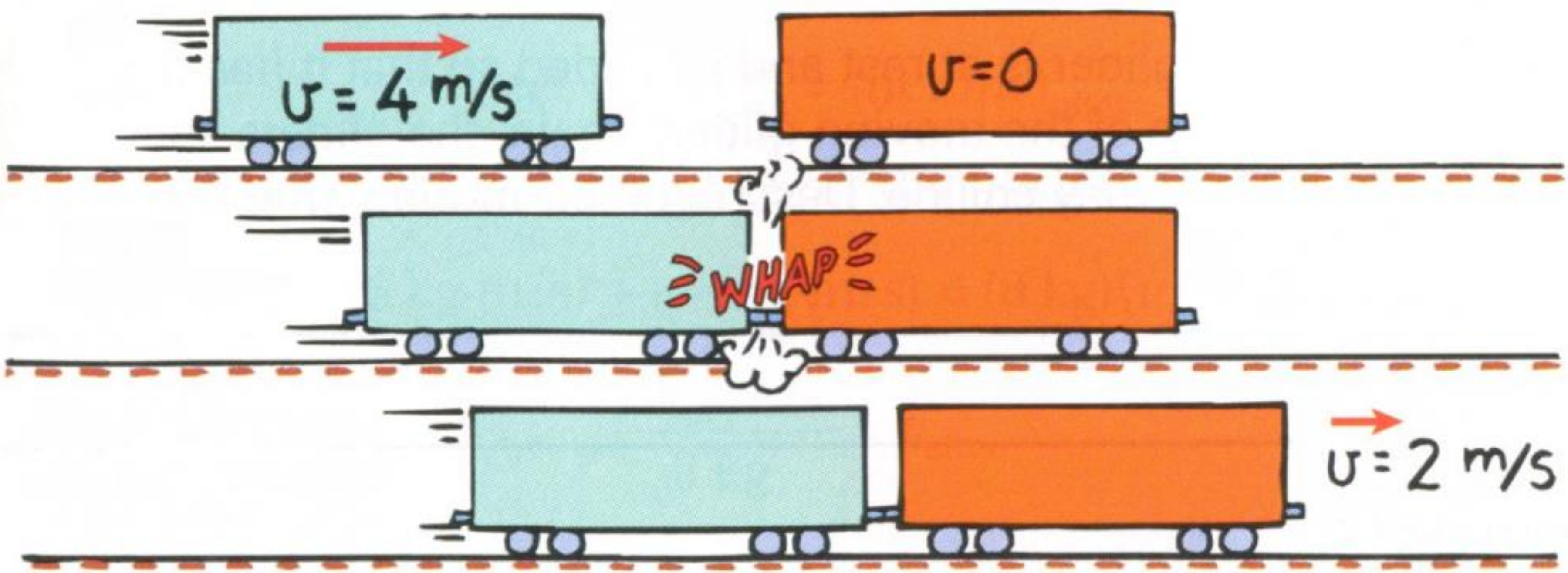
2. **Sum of momentum vectors** is the **same** before and after each collision



B. Inelastic Collisions

1. **Inelastic Collisions**- *Objects become distorted and generate heat during the collision (objects become tangled or couple together)*

2. You can **predict velocity** of the coupled objects after impact

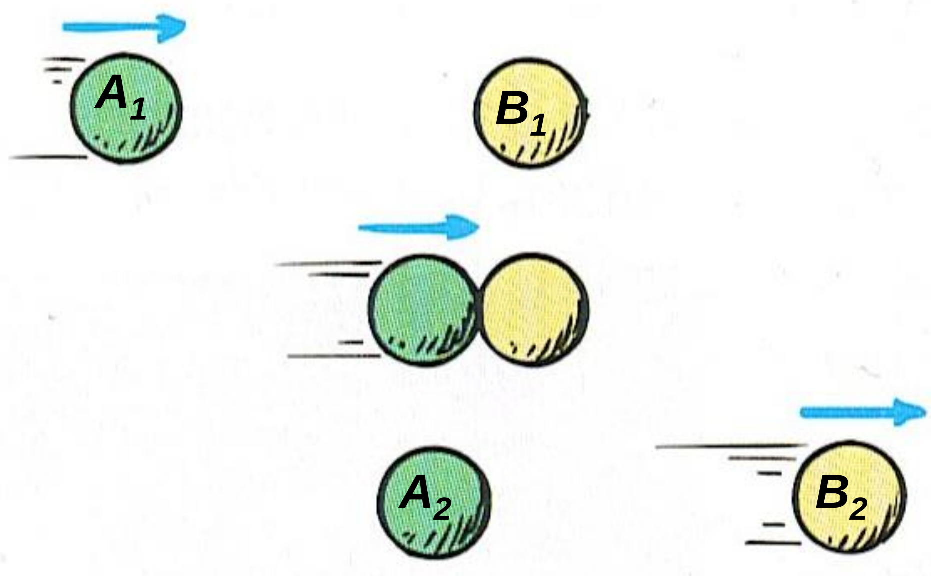


net momentum before collision = net momentum after collision

Or in equation form

$$(\text{net } mv)_{before} = (\text{net } mv)_{after}$$

$$p_{A1} + p_{B1} = p_{A2} + p_{B2}$$



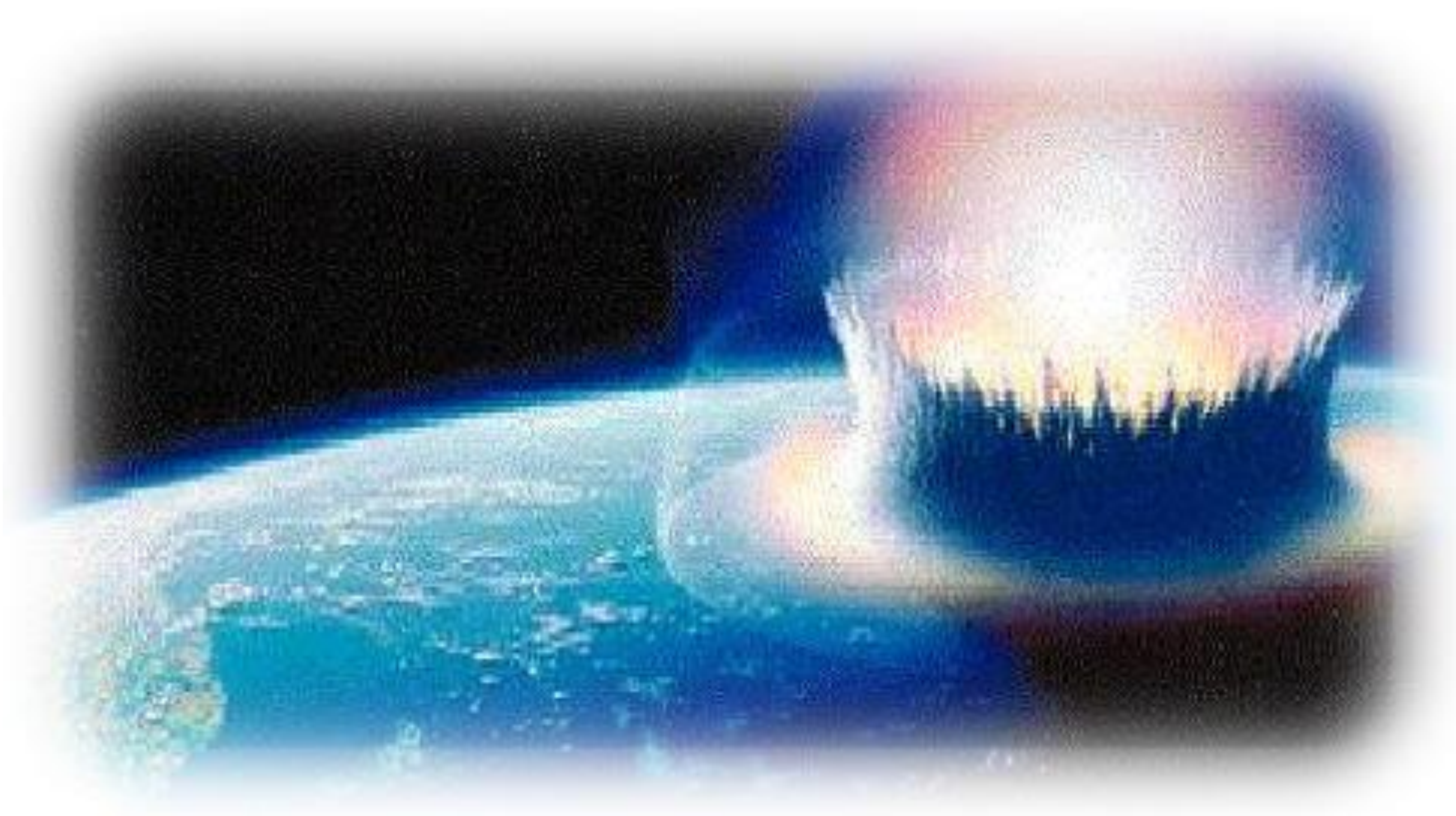
3. Most collisions usually involve some external force

   a. Most external forces are negligible during collision

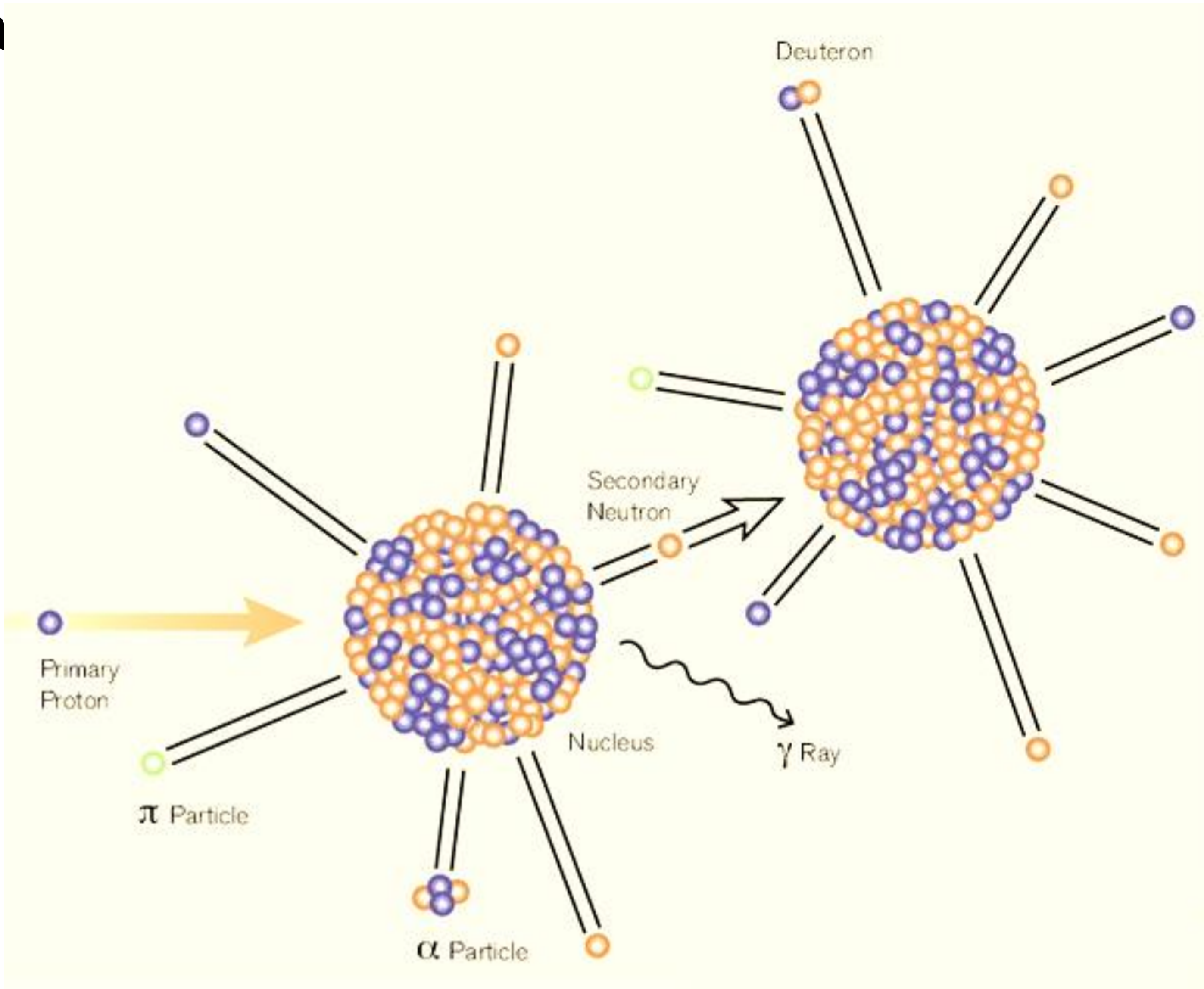
   b. Friction may play a role after collisions

C. Perfect elastic collisions are not common in everyday world

1. Heat is usually generated



2. Perfectly elastic collisions commonplace at a microscopic level (e.g. electrically charged pa

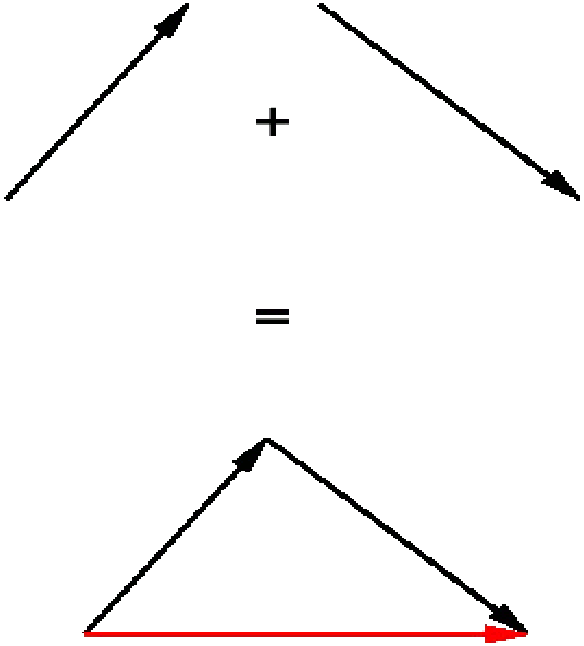


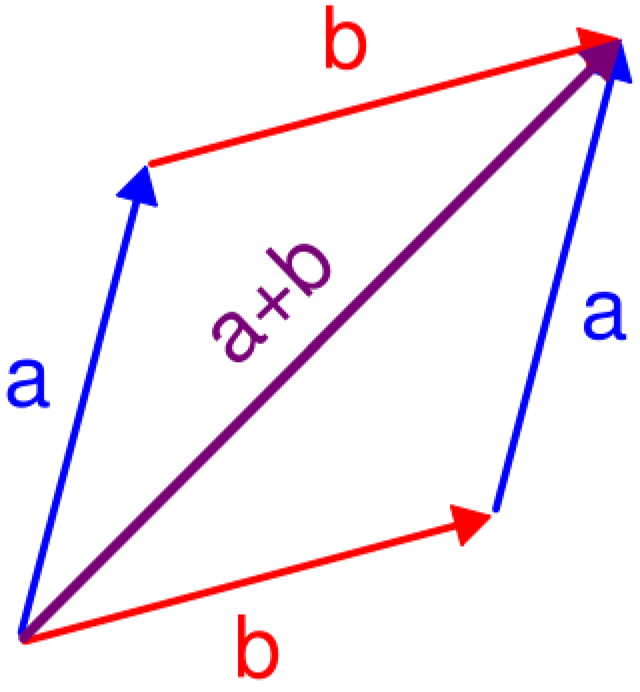
VI. Momentum Vectors (7.6)

A. Momentum conserved even if interacting objects don't move along the same straight line

1. Use **vectors** to analyze

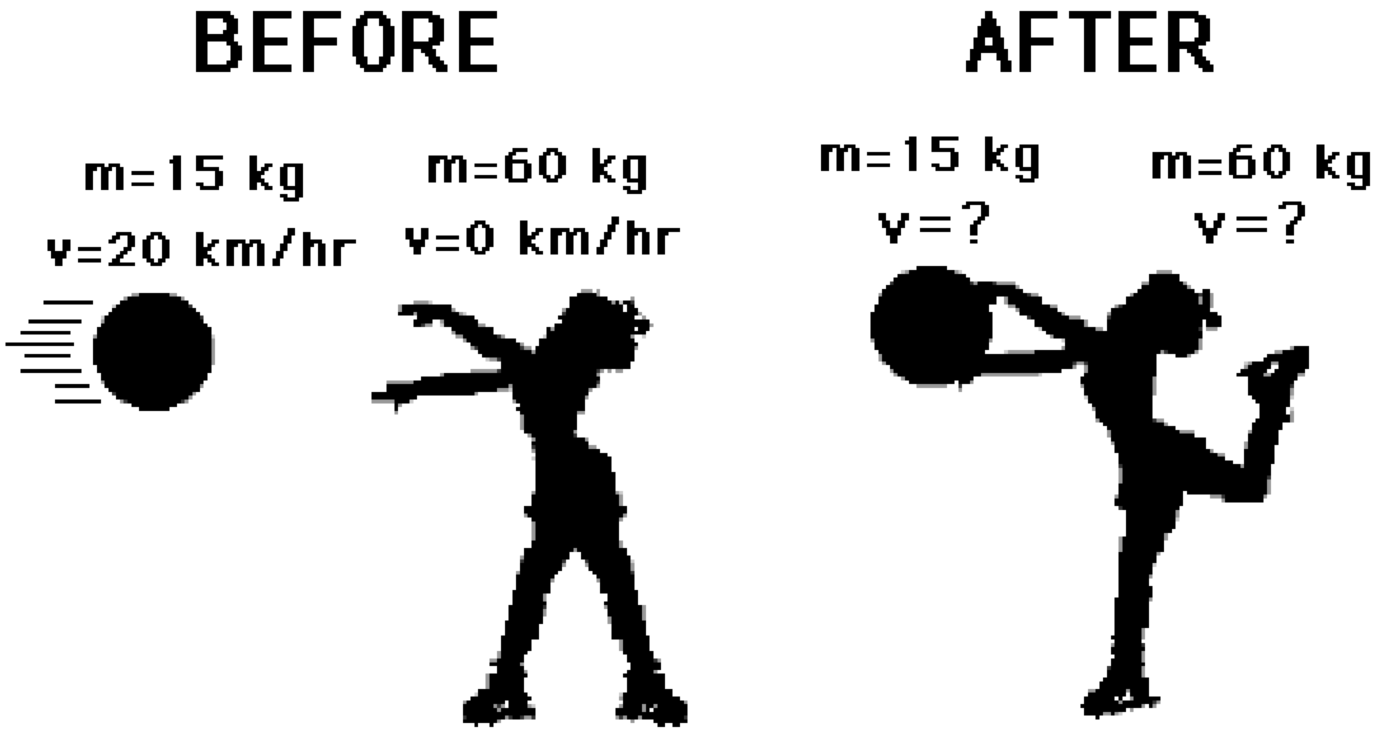
2. Momentum is the vector sum of two objects





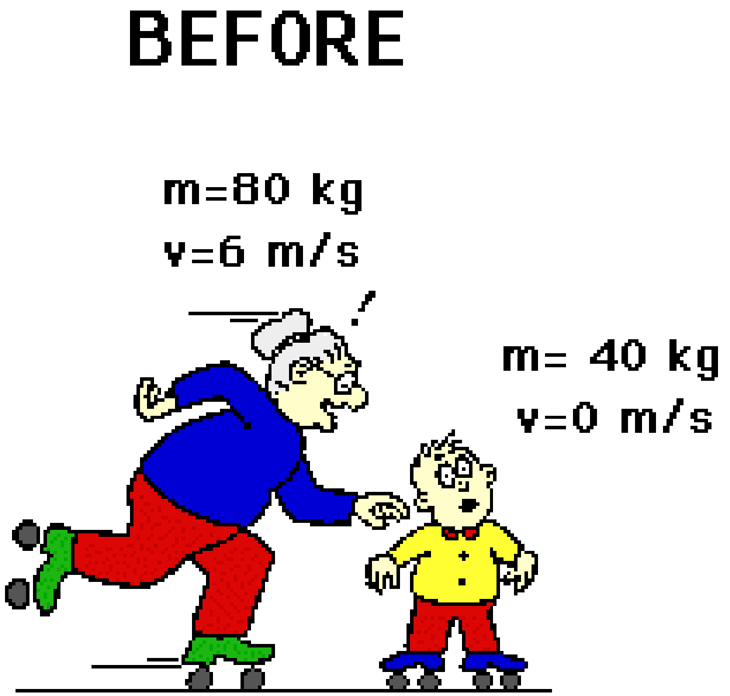
A 15-kg medicine ball is thrown at a velocity of 20 km/hr to a 60-kg person who is at rest on ice. The person catches the ball and subsequently slides with the ball across the ice. Determine the velocity of the person and the ball after the collision.

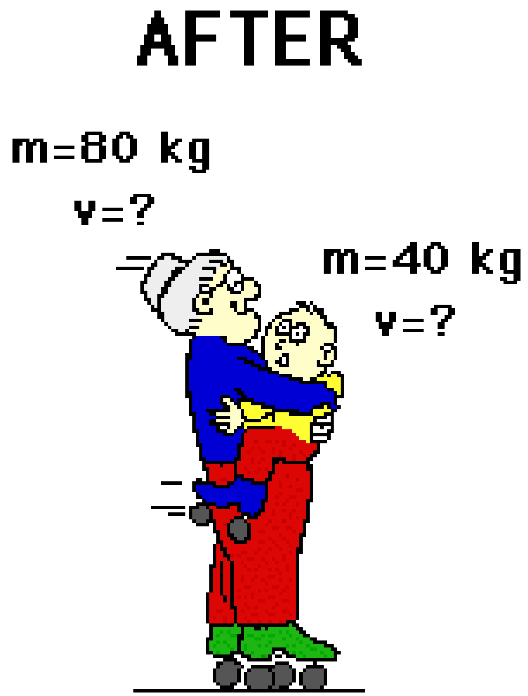
Such a motion can be considered as a collision between a person and a medicine ball. Before the collision, the ball has momentum and the person does not. The collision causes the ball to lose momentum and the person to gain momentum. After the collision, the ball and the person travel with the same velocity ("v") across the ice.



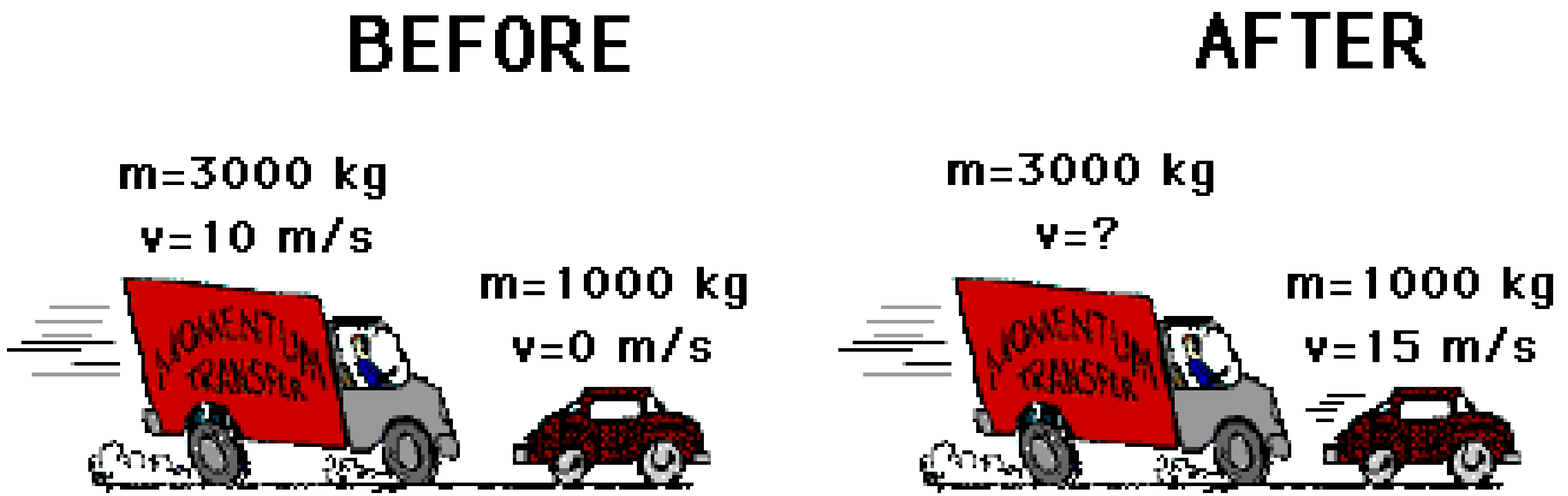
Granny (m=80 kg) whizzes around the rink with a velocity of 6 m/s. She suddenly collides with Ambrose (m=40 kg) who is at rest directly in her path. Rather than knock him over, she picks him up and continues in motion without "braking." Determine the velocity of Granny and Ambrose. Assume that no external forces act on the system so that it is an isolated system.

Before the collision, Granny has momentum and Ambrose does not. The collision causes Granny to lose momentum and Ambrose to gain momentum. After the collision, the Granny and Ambrose move with the same velocity ("v") across the rink.



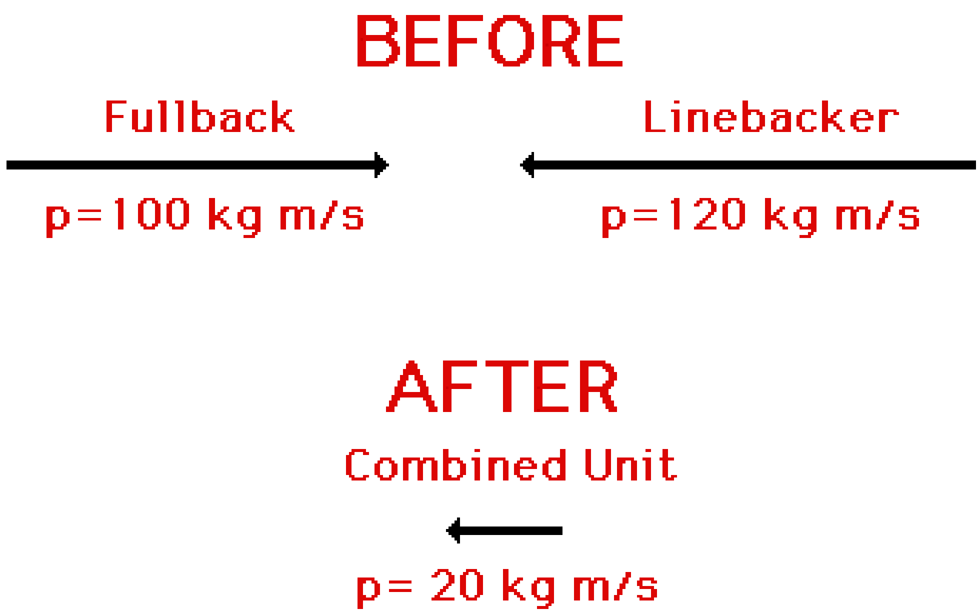


A 3000-kg truck moving with a velocity of 10 m/s hits a 1000-kg parked car. The impact causes the 1000-kg car to be set in motion at 15 m/s. Assuming that momentum is conserved during the collision, determine the velocity of the truck after the collision. In this collision, the truck has a considerable amount of momentum before the collision and the car has no momentum (it is at rest). After the collision, the truck slows down (loses momentum) and the car speeds up (gains momentum). The collision can be analyzed using a momentum table similar to the above situations.



	Before Collision	After Collision
Truck	3000 * 10 = 30 000	3000 * v
Car	0	1000 * 15 = 15 000
Total	30 000	30 000

Collisions commonly occur in contact sports (such as football) and racket and bat sports (such as baseball, golf, tennis, etc.). Consider a collision in football between a fullback and a linebacker during a goal-line stand. The fullback plunges across the goal line and collides in midair with linebacker. The linebacker and fullback hold each other and travel together after the collision. The fullback possesses a momentum of 100 kg*m/s, East before the collision and the linebacker possesses a momentum of 120 kg*m/s, West before the collision. The total momentum of the system before the collision is 20 kg*m/s, West (review the section on adding vectors if necessary). Therefore, the total momentum of the system after the collision must also be 20 kg*m/s, West. The fullback and the linebacker move together as a single unit after the collision with a combined momentum of 20 kg*m/s. Momentum is conserved in the collision. A vector diagram can be used to represent this principle of momentum conservation; such a diagram uses an arrow to represent the magnitude and direction of the momentum vector for the individual objects before the collision and the combined momentum after the collision.



Now suppose that a medicine ball is thrown to a clown who is at rest upon the ice; the clown catches the medicine ball and glides together with the ball across the ice. The momentum of the medicine ball is 80 kg*m/s before the collision. The momentum of the clown is 0 m/s before the collision. The total momentum of the system before the collision is 80 kg*m/s. Therefore, the total momentum of the system after the collision must also be 80 kg*m/s. The clown and the medicine ball move together as a single unit after the collision with a combined momentum of 80 kg*m/s. Momentum is conserved in the collision.